Ohio Agricultural Experiment Station.

BULLETIN 94

WOOSTER, OHIO, JUNE, 1898.

THE MAINTENANCE OF FERTILITY.

FIELD EXPERIMENTS WITH FERTILIZERS.

in 1897.

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BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 94. JULY, 1898.

FIELD EXPERIMENTS WITH FERTILIZERS.*

1. FERTILIZERS ON CROPS GROWN IN 5-YEAR ROTATION.

In this experiment, corn, oats and wheat are grown in succession, one year each, followed by clover and timothy two years. The soils under experiment are (1) the light, yellow clay of the central station in Wayne county, (2) the heavy, white clay of the Northeastern sub-station at Strongsville, Cuyahoga county, and (3) the black upland (beech and elm) of that portion of the farm of the State University at Columbus on which this particular test is located.

The plan of the experiment at the central station and the Northeastern sub-station is the same, except that the latter test includes ten additional plots. In this plan, "superphosphate" has hitherto meant dissolved bone black, and is applied at the rate of 80 pounds per acre, when used as the only carrier of phosphoric acid, or in quantities sufficient to bring up the total application of phosphoric acid to that contained in 80 pounds of dissolved bone black on corn and oats and 160 pounds on wheat, when used in connection with other phosphatic materials. When other carriers of phosphoric acid (wheat bran, acid phosphate and slag meal) are used as the sole carriers of phosphoric acid the quantity applied

*The Director of the station is responsible for the general plan of these experiments and for the discussion of results. The field work at the central station has been executed under the immediate supervision of the Agriculturist of the station, in the case of the cereal and hay crops, and under that of the Horticulturist in the case of potatoes. These gentlemen have also assisted in the conduct of the work at the sub-stations. The fertilizers used have been analyzed by the Chemist and Assistant Chemist of the station.

Bulletins 71 and 80 give the plan of these experiments and the results attained up to the end of the year 1896. The present Bulletin reports the continuance of the work for 1897.

is intended to carry the same amount of phosphoric acid as that found in the standard dressing of dissolved bone black.[1]

Nitrate of soda is used as the standard carrier of nitrogen ("ammonia") and is applied at the rate of 160 pounds per acre when used alone, or in quantities sufficient to bring up the total nitrogen to that found in 160 pounds of nitrate of soda when used in connection with other nitrogen carrying materials (wheat bran, oil meal, bone meal) except on Plot 12, where the nitrate is increased to 240 pounds, and on Plots 32 and 33 at Strongsville, where it is reduced to 80 pounds and 40 pounds respectively.

Muriate of potash is used as the carrier of potash, and is applied uniformly at the rate of 80 pounds per acre on corn and oats and 100 pounds on wheat, except on Plots 17 and 21, where allowance is made for the potash in the bran and oil meal; on Plot 30, where it is used at the rate of 10 pounds only, and on Plots 35 and 36 at Strongsville, where the quantity is reduced to 40 and 20 pounds respectively.

On Plot 17 wheat bran is used as the carrier of all the phosphoric acid and part of the nitrogen and potash, and on Plot 21 linseed oil meal is used as the carrier of all the nitrogen and part of the phosphoric acid and potash. On Plot 23 dried blood, and on Plot 24 sulphate of ammonia is substituted for nitrate of soda. On Plot 26 raw bone meal is used as the carrier of the phosphoric acid and part of the nitrogen, the total nitrogen being brought up, by the addition of nitrate of soda, to the quantity used on other standard plots. On Plot 27 acid phosphate,[2] and on Plot 29 basic slag is used as the carrier of phosphoric acid.[3] On Plot 30 is used a mixed fertilizer, having approximately the composition of the average ready mixed fertilizers sold in the state. For the crops of 1894 and 1895, at the central station, this fertilizer was mixed from dissolved bone black, nitrate of soda and muriate of potash. In 1895 a ready mixed fertilizer, having approximately the same analysis, ("ammonia, 3 to 4 per cent., phosphoric acid, 8 to 10 per cent., potash, 2 to 2½ per cent.") was used at Strongsville, and in 1896 the fertilizer was mixed from tankage, acid phosphate and muriate of potash for both experiments.

In the tests herein reported the corn was grown on old sod land at Strongsville and Wooster in 1894, and on land that had grown cowpeas and clover the preceding season at Wooster in 1895 and 1896. In 1897 it followed clover and timothy at Wooster and navy beans at Strongsville. The land at Wooster was underdrained by tile drains laid 36 feet apart, in 1893. That at Strongsville had not been drained previous to 1897, but was

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[1] Beginning with the spring of 1897 acid phosphate is substituted for dissolved bone black as the standard carrier of phosphoric acid.

[2] Dissolved bone black is substituted for acid phosphate on this plot, beginning with the spring of 1897.

[3] In Bulletin 80, page 144, read 27 and 29 in this statement instead of 26 and 27.

plowed in narrow lands, giving partial surface drainage. 1895 was a dry season, and the crop was exceptionally good for that land, but in 1896 it suffered from excess of rain. In 1897 all the land at Strongsville was drained except Section E.

In both 1895 and 1896 the wheat crop on the thin land on which this test is located at the central station suffered severely from winter killing followed by spring drouth, the average yield of the unfertilized plots falling to three bushels per acre in 1895, and to one bushel in 1896. The destruction of crop was only partially prevented by fertilizers. On the heavy clay of the sub-station the wheat was so completely destroyed that no attempt was made to harvest it separately; the most heavily fertilized plots showed but little if any more wheat than the unfertilized plots at the central station. At Columbus the wheat in both the continuous and rotative culture was almost as completely destroyed as at Strongsville. It was harvested carefully, but it was mixed with a heavy growth of weeds, and the continuous rains of July rotted it in the shock, and though an attempt was made to thresh it separately, no trustworthy data as to yield could be obtained.

Table I gives the plan of fertilizing in this experiment. Table II shows the total quantity of fertilizing materials applied per acre in the five years of a rotation, with estimated quantity of fertilizing constituents carried and cost of total application. Tables III to VI give the yields and increase per acre from each fertilizer for 1897, both at the central station and at the sub-station, and Tables VII and VIII give the average increase since the beginning of the test at both stations, with the total value of the increase from a single rotation, based on the average crop.

It will be observed that the harvests of 1897 show a handsome profit on the fertilizers in every case except where nitrogen and potash are used singly or in combination, whereas in the average of the four seasons, as shown in Table VII, the fertilizers have generally been used at a loss.

This is in part explained by the unfavorable weather conditions of 1895 and 1896, which not only reduced the crops on the unfertilized land almost to total destruction in some cases, but also reduced the fertilized crop to such an extent as to leave a very narrow margin of increase.

The impotence of added fertility to counteract unfavorable seasonal conditions is shown in the experiment in the continuous culture of wheat on the same land on the farm of the State University at Columbus. The crop was totally destroyed in 1896, but in 1897 the land which had been sown to wheat for nine years in succession, without having received any fertilizer of any description, yielded thirty-nine bushels of wheat per acre.

No attempt is made to estimate the profit or loss per acre from fertilizers at the Northeastern sub-station separately, as only four of the five crops of the rotation have as yet been harvested there. The large yield of wheat in 1897, reaching forty bushels and over per acre in some cases, shows that the apparently refractory clay of this region may be brought into a condition of great productiveness.

The principal questions for which answers are sought in this experiment may be stated as follows:

1. What is the relative importance, in a fertilizer prepared for soils similar to those under test, of nitrogen, phosphoric acid and potash respectively?

2. May one or two of these constituents be omitted altogether from a fertilizer for these soils, especially when clover is grown regularly in rotation with the cereals?

3. In what ratio to each other may the fertilizing constituents be most economically used?

4. Upon what crops in the rotation may fertilizers be used to the best advantage?

5. In what forms or carriers may they be most cheaply furnished?

(Continued on page 305.)

TABLE I—PLAN OF FERTILIZING IN FIVE-YEAR ROTATION, CENTRAL STATION AND N. E. SUB-STATION.

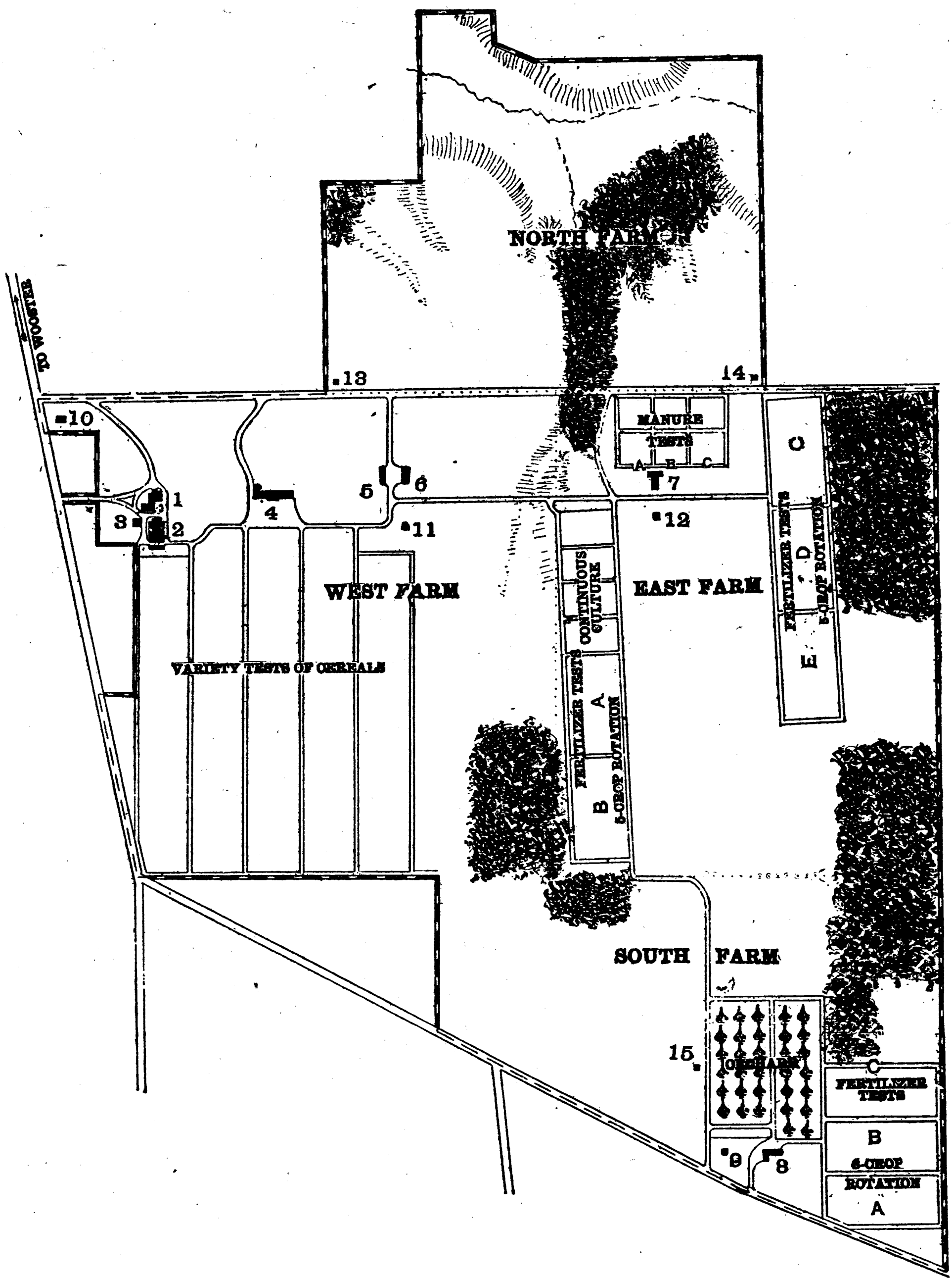
Fertilizers in pounds per acre.

Plot No.	On corn.			On oats.			On wheat.		
	Superphosphate.[1]	Nitrate soda.	Muriate potash.	Superphosphate.[1]	Nitrate soda.	Muriate potash.	Superphosphate.[1]	Nitrate soda.[2]	Muriate potash.
1									
2	80			80			160		
3			80			80			100
4									
5		160			160			160	
6	80	160		80	160		160	160	
7									
8	80		80	80		80	160		100
9		160	80		160	80		160	100
10									
11	80	160	80	80	160	80	160	160	100
12	80	240	80	80	240	80	160	240	100
13									
14	80	160	80				160	160	100
15							160	160	100
16									
17	A	80	65	A	80	65	B		70
18	C						C		
19									
20	D						D		
21	30	E	70	30	E	70	110	E	90
22									
23	70	F	80	70	F	80	140	F	100
24	80	G	80	80	G	80	160	G	100
25									
26	H	150	80	H	150	80	I	135	100
27	K	160	80	K	160	80	L	160	100
28									
29	M	160	80	M	160	80	N	160	100
30	O						O		
31									
32	80	80	80	80	80	80	160	80	100
33	80	40	80	80	40	80	160	40	100
34									
35	80	160	40	80	160	40	160	160	50
36	80	160	20	80	160	20	160	160	25
37									
38							P		
39							Q		
40									

[1]Superphosphate as dissolved bone black previous to 1897; as acid phosphate, beginning with spring of 1897.

[2]On wheat, one-third dried blood, applied in the fall, and two-thirds nitrate of soda, applied in April; all other fertilizers for wheat are applied in the fall.

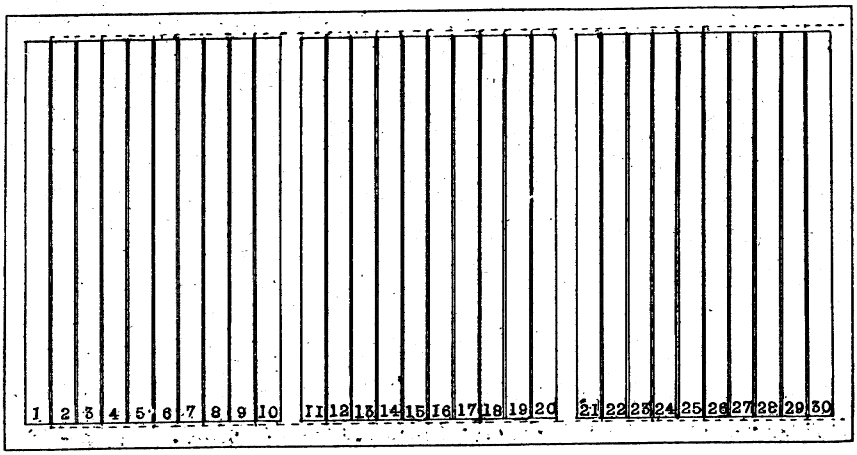
A Wheat bran, 500 pounds.
B Wheat bran, 1,000 pounds.
C Barnyard manure, eight tons on wheat and corn only.
D Barnyard manure, four tons on wheat and corn only.
E Linseed oil meal, 500 pounds.
F Dried blood, 200 pounds.
G Sulphate of ammonia, 120 pounds.
H Raw bone meal, 55 pounds.
I Raw bone meal, 110 pounds.
K Acid phosphate, 85 pounds, previous to 1897; dissolved bone black, 70 pounds, 1897 and since.
L Acid phosphate, 170 pounds
M Basic slag, 65 pounds.
N Basic slag, 130 pounds.
O Mixed fertilizer, 210 pounds on corn and wheat only.
P Mixed fertilizer, 420 pounds on wheat only.
Q Barnyard manure, 16 tons on wheat only.
Plots 31 to 40, inclusive, at N. E. sub-station only.



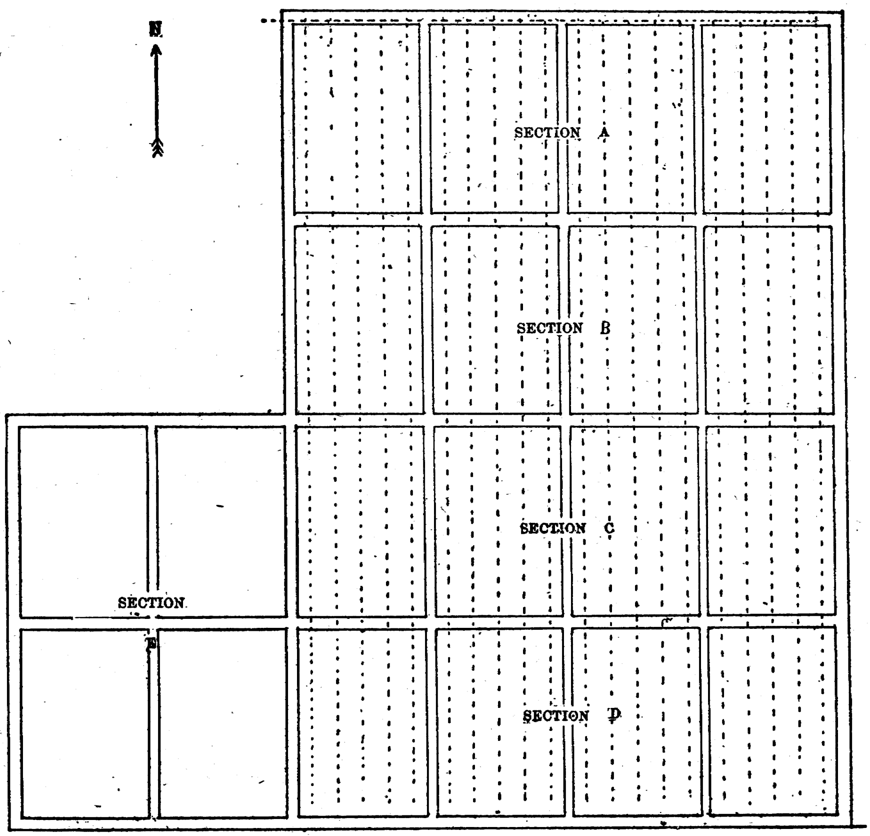
FARM MAP—OHIO AGRICULTURAL EXPERIMENT STATION.

1. Main Building.
2. Greenhouses.
3. Biological Laboratory.
4. Dairy Barn and Creamery.
5. Tool House.
6. Horse Barn.
7. East Barn.
8. Horticultural Barn and Cold Storage.
9. Residence of Horticulturist.
10. Residence of Director.

11, 12, 13, 14, 15. Dwellings Occupied by Foremen and Laborers.



PLAN of sections in five-year rotation at central station. The same arrangement is followed at the sub-station, except that there are forty plots to the section instead of thirty. Dotted lines indicate drains.



PLAN of five-year rotation at Northeastern sub-station, showing arrangement of sections and drains.

EXPLANATION OF MAP AND PLANS.

In the accompanying farm map of the central station is shown the general plan of the fertilizer tests. The five-year rotation is located on the East farm, occupying the crests of two low ridges which run nearly north and south, at a slight angle with the farm boundaries. This test is divided into five sections, A, B, C, D and E, and is so conducted that each crop is represented each season. Section C was in corn in 1893, Section D in 1894, Section E in 1895, Section B in 1896, Section A in 1897 and Section C again in 1898. The corn crop of 1893 was so nearly a failure that it has not been included in the computations which follow. Oats has followed corn regularly through the rotation, beginning on Section C in 1894; wheat was grown on Section A in 1894 and was fertilized according to the plan, thus giving four crops of each cereal up to 1897.

Each section in this test is divided into thirty plots, of one-tenth acre each, the plots being sixteen feet wide by 272½ feet long, and separated by dividing spaces two feet in width. Tile drains are laid under alternate dividing spaces, at a depth of thirty inches. These drains empty into mains at the ends of the plots. The drains are indicated by dotted lines in the plans accompanying. The plots are slightly ridged to prevent surface water from washing across them, and thus carrying fertility from one to another. They are arranged in blocks of ten, and these blocks are separated by roadways twelve feet wide, to facilitate the harvesting. Grain is grown in these roadways to equalize conditions, but it is cut out first, thus permitting the harvesting of the grain in blocks, cutting both ways. Of course the machine must run empty around the ends of the plots.

Each section is surrounded by a roadway eighteen or twenty feet wide.

The accompanying plan shows in detail the arrangement of the plots on one of these sections.

At the Northeastern sub-station this work is located in a field which slopes gently and uniformly to the north. The general plan is shown in the diagram, which gives the arrangement of the sections, and of the drains as shown by the dotted lines; each section in this test contains forty plots, which are arranged in the same manner as those in the tests at the central station. Section E of this test has not been drained.

The cropping began with corn, which was grown on Section D in 1895 and is now growing on Section B; oats has followed corn regularly according to plan; wheat was sown on Section C in the fall of 1895 and fertilized according to plan, but was completely destroyed by winter-killing. The wheat crop of 1897 was grown on Section D.

TABLE II—FERTILIZERS ON CROPS GROWN IN FIVE-YEAR ROTATION.

Total quantity of fertilizing materials applied per acre during the five years of a rotation, with fertilizing constituents carried and cost of total application.

Plot No.	Fertilizing materials.				Fertilizing constituents.			
	Super-phos-phate.	Nitrate of soda.	Muriate of potash.	Total.	Phos-phoric acid.	Nitrogen	Potash.	Cost of fertil-izers.
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	
2	320	....	....	320	50	....	....	$2 40
3	....	....	260	260	....	....	130	6 50
5	....	480	....	480	....	75	....	12 00
6	320	480	....	800	50	75	....	14 40
8	320	....	260	580	50	....	130	8 90
9	....	480	260	740	....	75	130	18 50
11	320	480	260	1,060	50	75	130	20 90
12	320	720	260	1,300	50	112	130	26 90
14	240	320	180	740	38	50	90	14 30
15	160	160	100	420	25	25	50	7 70
17	A	160	200	1,860	50	75	130	19 00
18	....	....	....	32,000	100	150	160	8 00
20	....	....	....	16,000	50	75	80	4 00
21	170	B	230	1,900	51	81	135	22 00
23	320	C	260	1,180	50	75	130	17 30
24	320	D	260	940	50	74	130	19 70
26	E	435	260	915	50	77	130	20 12
27	F	480	260	1,080	50	75	130	20 90
29	G	480	260	1,000	50	75	130	20 90
30	200	H	20	420	50	12	10	3 75
32	320	240	260	820	50	38	130	14 90
33	320	120	260	700	50	19	130	11 90
35	320	480	130	930	50	75	65	17 65
36	320	480	65	865	50	75	32	16 03
38	200	H	20	420	50	12	10	3 75
39	....	....	....	32,000	100	150	160	8 00

A Wheat bran, 1,500 pounds.
B Linseed oil-meal, 1,500 pounds.
C Dried blood, 600 pounds.
D Sulphate ammonia, 360 pounds.
E Bone meal, 220 pounds.
F Acid phosphate, 340 pounds, 1894-96. Dissolved bone black, 280 pounds, 1897.
G Basic slag, 260 pounds.
H Tankage, 200 pounds. Superphosphate as acid phosphate.

TABLE III—FERTILIZERS ON CROPS GROWN IN FIVE-YEAR ROTATION AT CENTRAL STATION.

Yield per Acre—1897.

Plot No.	Corn—Section A.		Oats—Section B.		Wheat—Section E.		Clover—Sec. D.	Timothy. Sec. C.
	Grain.	Stover.	Grain.	Straw.	Grain.	Straw.	Hay.	Hay.
	Bushels.	Pounds.	Bushels.	Pounds.	Bushels.	Pounds.	Pounds.	Pounds.
1	18.82	1,320	42.18	1,250	14.25	1,645	1,660	2,710
2	24.64	1,640	47.18	1,460	20.58	2,235	2,730	3,290
3	34.93	2,100	44.06	1,220	14.67	1,500	1,910	3,240
4	31.54	1,820	40.00	1,110	12.17	1,240	1,890	2,760
5	31.57	1,780	45.94	1,430	17.00	1,900	2,320	3,520
6	40.46	2,110	48.44	1,350	27.83	3,490	3,930	4,100
7	27.93	1,600	40.31	1,110	12.17	1,290	2,060	2,590
8	35.93	2,100	48.44	1,480	20.42	2,255	3,960	2,000
9	30.32	1,840	48.75	1,510	14.17	1,405	2,560	2,710
10	24.57	1,600	44.37	1,180	9.83	1,010	2,090	2,610
11	33.89	1,900	61.56	2,080	30.58	3,665	4,350	3,580
12	37.18	2,050	62.50	2,450	34.33	4,150	4,270	2,800
13	23.75	1,480	41.87	1,360	9.83	1,050	2,510	2,280
14	33.11	1,990	44.37	1,230	28.83	3,420	4,310	3,520
15	22.54	1,600	38.75	1,160	27.92	3,125	3,390	2,550
16	15.36	1,240	36.56	1,050	9.33	960	2,060	2,420
17	31.79	2,050	47.50	1,390	17.33	2,030	3,660	2,850
18	45.96	2,700	36.87	1,040	17.41	1,925	4,660	3,600
19	25.32	1,630	36.87	890	9.00	840	2,540	2,600
20	44.54	2,480	37.50	1.050	12.92	1,495	3,310	3,900
21	37.39	2,200	50.31	1,470	28.33	3,320	4,060	2,950
22	23.57	1,650	37.18	860	8.00	730	1,940	2,250
23	37.60	2,420	52.18	1,700	21.42	2,265	4,100	3,200
24	42.07	2,390	58.12	1,790	23.42	2,675	3,590	3,300
25	32.36	2,200	36.56	1,230	9.83	910	2,030	2,800
26	42.86	2,550	56.87	1,730	26.17	2,870	3,600	4,600
27	41.14	2,520	57.50	1,880	28.00	2,930	2,740	4,650
28	35.43	2,100	37.18	1,090	9.92	865	1,300	4,520
29	44.68	2,590	49.67	1,410	28.83	3,300	3,390	5,050
30	40.82	2,390	33.43	780	18.92	1,985	3,230	5,100
*	25.86	1,664	39.31	1,113	10.43	1,059	2,008	2,754

*Average of unfertilized plots.

TABLE IV—FERTILIZERS ON CROPS GROWN IN FIVE-YEAR ROTATION AT NORTHEASTERN SUB-STATION.

Yield per Acre—1897.

Plot No.	Corn—Section A.		Oats—Section E.		Wheat—Section D.		Hay—Section C.
	Grain.	Stover.	Grain.	Straw.	Grain.	Straw.	
	Bushels.	Pounds.	Bushels.	Pounds.	Bushels.	Pounds.	Pounds.
1........	24.71	1,450	30.31	890	10.33	860	1,550
2........	24.86	1,630	40.62	1,240	24.93	3,090	2,070
3........	19.71	1,240	34.37	940	13.08	1,215	1,560
4........	15.65	1,220	34.22	965	16.50	1,590	1,010
5........	13.00	1,200	34.06	970	15.17	1,410	1,340
6........	19.00	1,240	45.62	1,320	30.17	3,490	2.040
7........	12.50	1,450	32.97	925	16.50	1,630	2,180
8........	22.07	1,020	41.56	1,230	23.08	2,555	2,180
9..	17.00	1,420	31.56	890	20.00	2,160	1,840
10........	23.14	1,430	30,00	960	13.92	1,425	1,500
11........	36.86	1,940	42.50	1,480	25.67	2,660	2,050
12........	33.57	1,860	43.33	1,630	33.67	3,930	1,580
13........	25.86	1,480	35.47	1,085	12.83	1,190	1,590
14........	27.21	1,700	38.44	1,230	29.33	3,220	3,080
15........	16.14	1,340	31.72	1,025	27.00	2,880	2,250
16........	18.64	1,360	36.22	1,120	15.67	1,480	1,610
17........	26.36	1,520	34.53	1,135	16.17	1,510	2,220
18........	25.57	1,440	38.28	1,285	27.67	2,980	2,100
19........	21.29	1,330	33.12	980	8.83	770	1,270
20........	32.79	1,650	30.31	1,130	20.00	1,900	1,620
21........	33.29	1,680	39.69	1,270	18.04	1,737	1.960
22........	26.50	1,340	33.12	940	15.08	1,495	1,540
23........	28.36	1,560	44.38	1,420	24.50	2,450	2,350
24........	32.00	1,860	43.60	1,405	28.67	2,900	1,980
25........	24.50	1,560	28.28	795	14.04	1,357	1,500
26........	24.57	1,680	40.31	1,210	29.58	3,005	1,910
27........	27.50	1,700	43.75	1,340	23.50	2,310	1,820
28........	14.36	1,220	28.44	890	18.58	1,745	1,560
29........	28.86	1,660	38.91	1,255	32.00	3,400	2,120
30........	29.00	1,520	34.84	1,065	29.58	3,265	2,500
31..	17.57	1,380	24.84	805	13.12	1,212	1,380
32........	25.36	1,520	33.44	1,030	27.75	2,935	2,260
33........	22.50	1,240	35.31	1,150	22.75	2,315	2,160
34........	14.71	1,350	25.62	800	16.37	1,597	1,130
35........	22.36	1,340	37.66	1,275	28.83	2,870	1,750
36........	25 79	1,560	37.66	1,235	32.00	3,380	1,880
37........	19.86	1,360	27.81	830	15.83	1,370	750
38........	16.00	1,320	30.94	810	27.83	2,870	2,120
39........	12.93	1,060	30.62	840	24.33	2,260	1,220
40........	19.64	1,360	29.22	885	16.50	1,470	1,130
*	19.92	1,378	30.67	919	19.64	1,779	1,410

*Average of unfertilized plots.

TABLE V—FERTILIZERS ON CROPS GROWN IN FIVE-YEAR ROTATION AT CENTRAL STATION.

Increase or decrease (—) per acre—1897. [1]

Plot No.	Corn, Sec. A. Grain.	Corn, Sec. A. Stover.	Oats, Sec. B. Grain.	Oats, Sec. B. Straw.	Wheat, Sec. E. Grain.	Wheat, Sec. E. Straw.	Hay, Sections C & D.	Total value of increase [2]	Total cost of fertilizer.	Net gain or loss (—) from fertilizer.
	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Lbs.			
2	1.58	153	5.73	257	7.02	725	1,556	$13 94	$2 40	$11 54
3	7.63	447	3.33	63	1.81	125	594	7 56	6 50	1 06
5	1.23	33	5.84	320	4.83	643	1,190	12 30	12 00	30
6	11.33	437	8.23	240	15.66	2,217	3,380	32 85	14 40	18 45
8	9.12	500	6.78	353	9.03	1,058	2,293	21 70	8 90	12 80
9	4.63	240	5.73	353	3.56	297	587	8 92	18 50	—9 58
11	9.59	340	18.02	840	20.75	2,642	3,200	39 63	20 90	18 73
12	13.16	530	19.80	1,150	24.50	3,114	2,310	43 06	26 90	16 16
14	12.15	590	4.27	—27	19.17	2,400	3,143	34 32	14 30	20 02
15	4.38	280	....	....	18.42	2,135	1,357	23 89	7 70	16 19
17	13.11	680	10.84	393	8.11	1,110	1,810	22 27	19 00	3 27
18	23.96	1,200	0.10	97	8.30	1,045	3,340	28 19	8 00	20 19
20	19.80	743	0.53	170	4.25	692	2,387	18 05	4 00	14 05
21	13.24	556	13.23	600	20.00	2,553	2,503	36 79	22 00	14 79
23	11.10	587	15.21	717	12.81	1,475	2,897	30 61	17 30	13 31
24	12.64	373	21.35	683	14 20	1,825	2,273	31 05	19 70	11 35
26	9.48	384	20.10	547	16.31	1,975	3,040	34 71	20 12	14 59
27	6.73	387	20.53	743	18.11	2,050	1,902	32 34	20 90	11 44
29	9.25	490	12.49	320	18.91	2,435	2,620	34 05	20 90	13 15
30	5.39	290	—3.75	—310	9.00	1,120	2,510	17 20	3 75	13 45

1. In this and subsequent tables the increase for the fertilized plots has been calculated on the assumption that if the yields of two neighboring unfertilized plots, 1 and 4, for example, were twenty-five and twenty-eight bushels, respectively, the unaided yield of the fertilized plots between, 2 and 3, would have been twenty-six and twenty-seven bushels. The "average yield of unfertilized plots" is given in each table for general comparison, but is not used in calculating the increase.

2. Rating corn at 33⅓ cents per bushel, oats at 25 cents, wheat at 80 cents, straw and stover at $3.00 per ton and hay at $6.00 per ton.

TABLE VI—FERTILIZERS ON CROPS GROWN IN FIVE-YEAR ROTATION AT NORTHEASTERN SUB-STATION.

Increase or decrease (—) per acre—1897.

Plot No.	Corn.		Oats.		Wheat.		Hay.
	Grain.	Stover.	Grain.	Straw.	Grain.	Straw.	
	Bushels.	Pounds.	Bushels.	Pounds.	Bushels.	Pounds.	Pounds.
2	3.17	257	9.01	325	12.54	1,987	660
3	1.04	—57	1.45	0	—1.36	—132	150
5	—1.60	—97	0.26	18	—1.33	—193	—70
6	5.45	—133	12.23	382	13.67	1,874	630
8	6.02	—423	9.58	293	7.44	993	770
9	—2.59	—17	0.57	—58	5.22	667	430
11	12.81	493	10.68	478	12.11	1,313	640
12	8.62	397	9.68	587	20.48	2,662	170
14	3.76	260	2.72	133	15.55	1,933	1,670
15	....	....	....	....	12.28	1,497	840
17	6.84	170	—0.66	62	2.78	267	810
18	5.16	100	4.13	258	16.56	1,973	690
20	9.76	317	—2.81	150	9.09	888	210
21	8.53	343	6.57	330	5.04	484	550
23	2.53	147	12.87	528	9.77	1,001	940
24	6.83	373	13.71	562	14.28	1,497	570
26	3.45	238	11.98	383	14.03	1,519	500
27	9.76	367	15.36	482	6.43	694	410
29	13.43	387	11.67	393	15.24	1,833	710
30	12.50	193	8.80	232	14.64	1,875	1,090
32	8.74	150	8.34	227	13.55	1,595	850
33	6.84	—120	9.95	348	7.46	846	750
35	5.93	—13	11.31	465	12.64	1,349	340
36	7.65	203	9.03	273	15.99	1,934	470
38	....	....	....	....	11.78	1,467	710
39	....	....	....	....	8.05	823	....

TABLE VII—FERTILIZERS ON CROPS GROWN IN FIVE-YEAR ROTATION AT CENTRAL STATION.

Average annual increase or decrease (—) per acre for four years—1894-1897.

Plot No.	Corn. Grain.	Corn. Stover.	Oats. Grain.	Oats. Straw.	Wheat. Grain.	Wheat. Straw.	Hay.	Total value of increase.	Total cost of fertilizer.	Net gain or loss(—) from fertilizer.
	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Lbs.			
2......	1.81	—48	4.89	131	3.00	451	402	$6 23	$2 40	$3 83
3......	2.68	51	1.30	—91	1.79	196	625	4 75	6 50	—1 75
5......	0.22	—5	3 49	15	1.37	215	523	3 95	12 00	—8 05
6......	7.75	172	8.94	256	5.59	866	1,745	16 45	14 40	2 05
8......	5.32	263	6.99	265	5.12	529	1,366	13 32	8 90	4 42
9......	0.00	156	2.21	76	2.19	177	720	5 07	18 50	—13 43
11......	8.74	282	13.57	575	8.98	1,268	1,611	21 51	20 90	0 61
12......	8.37	291	14.94	688	9.73	1,351	1,201	21 64	26 90	—4 26
14......	7.95	337	7.34	237	7.32	1,151	1,670	17 94	14 30	3 64
15......	....	....	....	....	6.33	892	717	8 55	7 70	0 85
17......	6.10	163	8.10	327	5.38	706	1,347	12 69	19 00	—6 31
18......	8.95	436	4.71	273	4.05	796	2,895	18 34	8 00	10 34
20......	6.00	295	2.32	197	2.96	567	2,216	13 18	4 00	9 18
21......	6.62	335	7.46	378	9.14	1,295	1,552	19 04	22 00	—2 96
23......	6.76	283	9.91	324	6.69	860	1,586	17 04	17 30	—0 26
24......	8.59	367	12.80	474	7.39	946	1,176	18 18	19 70	—1 52
26......	5.96	361	11.96	362	6.20	983	1,755	17 76	20 12	—2 34
27......	5.50	202	11.87	516	7.16	1,063	947	16 03	20 90	—3 87
29......	7.79	330	10.42	479	7.77	1,126	1,252	18 09	20 90	—1 81
30......	7.20	187	5.19	227	4.53	660	1,227	12 60	3 75	8 85

TABLE VIII—FERTILIZERS ON CROPS GROWN IN FIVE-YEAR ROTATION AT NORTHEASTERN SUB-STATION.

Average annual increase or decrease (—) per acre for three years—1895-97.

Plot No.	Corn.		Oats.		Wheat.		Hay.
	Grain.	Stover.	Grain.	Straw.	Grain.	Straw.	
	Bushels.	Pounds.	Bushels.	Pounds.	Bushels.	Pounds.	Pounds.
2	3 08	11	6.95	345	11.44	1,987	660
3	1.54	3	0.15	36	—1.36	—132	150
5	1.37	9	—0.79	143	—1.33	—193	—70
6	6.91	—3	10.64	337	13.67	1,874	630
8	2.71	—269	7.38	275	7.44	993	770
9	0.91	—71	1.67	298	5.22	667	490
11	11.07	247	10.79	481	12.11	1,313	640
12	7.84	230	10.09	490	20.48	2,695	170
14	5.64	136	4.85	186	15.55	1,933	1,670
15	....	....	....	....	12.28	1,497	840
17	2.92	11	4.94	324	2.78	267	810
18	7.55	81	6.36	217	16.56	1,973	690
20	5.20	55	0.73	134	9.09	888	210
21	4.68	89	4.77	407	5.04	484	550
23	4.86	—62	8.36	686	9.77	1,001	940
24	4.81	96	10.19	656	14.28	1,597	570
26	3.22	213	11.85	391	14.03	1,514	500
27	7.08	258	11.35	569	6.43	694	410
29	8.76	151	11.46	413	15.24	1,833	710
30	10.72	172	9.01	359	14.64	1,875	1,090
32	*5.11	100	10.24	478	13.55	1,595	850
33	*6.22	—28	11.37	573	7.46	846	750
35	*7.54	130	12.22	565	12.64	1,349	340
36	*8.68	222	12.47	515	15.99	1,934	470
38	....	....	....	....	11.78	1,467	710
39	....	....	....	....	8.05	823	....

*Average of two crops.

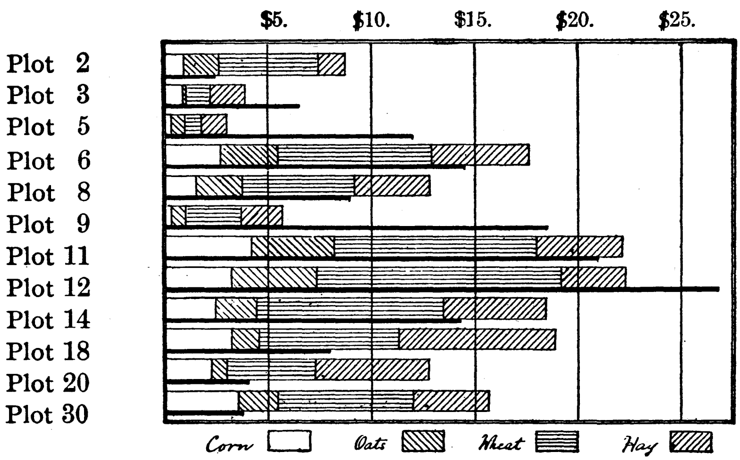
(Continued from page 294.)

To the first of these questions our experiments already give a decisive answer. Both at the central station and at the sub-station, especially the latter, it is phosphoric acid which is first needed, for the cereal crops at least. Potash and nitrogen, when used alone, have produced but a small increase in the cereals at the central station and none at the sub-station, and their effect is relatively small when used in combination with each other but without phosphoric acid. It should be noted here, however, that the field at the sub-station in which this test is located has been in pasture for twenty years or more, and although but little clover has been grown, there has been a considerable accumulation of nitrogen in the sod, while there has been a considerable removal of phosphoric acid in the bones and milk of the pastured animals. The land at the central station, on the other hand, had been under constant cultivation by tenants, with only occasional clover crops, and it would be expected that the relative effect of nitrogen, as compared with phosphoric acid, would be more marked here than at the sub-station.

When nitrogen and phosphoric acid are used in combination, as on Plot 9, the increase is greater than from either of them separately, but it is still small and irregular. When, however, phosphoric acid is combined with either nitrogen or potash, as on Plots 6 and 8, there is a decided increase in yield over that produced by phosphoric acid alone.

These points may be illustrated by the accompanying diagram, in which is shown the average value of the increase at the two stations from several of the fertilizing applications, the different shadings showing the proportion of the total value found in the increase of each crop, the straw or stover being included with the grain and the same prices being employed as those used in Tables IV and VII. This diagram is based upon the averages of seven crops of corn—four grown at the central station and three at the sub-station; six crops of oats—four at the central station and two at the sub-station; five crops of wheat—four at the central station and one at the sub-station, and six crops of hay—five at the central station and one at the sub-station, twenty-four crops in all. While, as already pointed out, there are certain differences indicated in the soils of the two stations, the general results agree so closely that it is probable that, at the present stage of the work, an average of the results of the two stations may be of more general application than those of either of the stations taken separately.

DIAGRAM I—AVERAGE VALUE OF INCREASE AND COST OF FERTILIZER PER ACRE IN FIVE-YEAR ROTATIONS.



This diagram shows at a glance that, in the general average, phosphoric acid (2) has given more than twice as great a value of total increase as that obtained from either potash (3) or nitrogen (5), and a fifty per cent. greater increase than that obtained from potash and nitrogen combined (9), although the phosphoric acid has been used in smaller quantity than either potash or nitrogen. It shows that when potash (3) has been added to phosphoric acid (2) the increase (8) is approximately equal to the sum of that obtained from the two used separately; but when phosphoric acid (2) is combined with nitrogen (5) the increase (6) is much greater than that from the two used separately.

When to this combination potash is added we have an additional increase (11) approximately equal to that produced by the potash alone, and an aggregate increase more than two and a half times as great as that produced by the phosphoric acid used alone.

When the quantity of nitrogen is increased, as on Plot 12, we have a still further increase in yield, shown altogether in the wheat crop, and indicating that nitrogen has not been employed on Plots 6 and 11 in quantity beyond the capacity of that crop to utilize it.

When the total quantity of fertilizer, as employed on Plot 11, is reduced by omitting it from the oat crop, the aggregate increase, as shown by line 14 of the diagram, is considerably reduced, but it is still greater than on Plot 6, although Plot 6 receives a total of 800 pounds of fertilizer and Plot 14 only 740 pounds.

It is therefore clear that in this first rotation it is the complete fertilizer, containing phosphoric acid, potash and nitrogen, all three, which is producing the greatest increase of crop. The problem next to be settled is whether this greater increase is being economically produced.

The heavy black lines in the diagram indicate the cost of the different fertilizing applications, as compared with the value of the increase produced; available phosphoric acid being rated at five cents per pound, potash at five cents (in the muriate) and nitrogen at its cost in nitrate of soda at fifty dollars per ton, which is equivalent to about sixteen cents per pound for nitrogen or thirteen cents for "ammonia."

It will be seen at once that both the potash and nitrogen have cost more than any increase they have produced, when used separately or in combination with each other only, while the phosphoric acid has given a handsome profit. Is it then advisable to use only phosphoric acid and content ourselves with the smaller rate of increase which it gives?

We have our answer to this question in Plot 30, a plot which is dressed with a mixture of 100 pounds each of acid phosphate and slaughter-house tankage, with ten pounds of muriate of potash, applied to corn and wheat—420 pounds in the total rotation and costing but $3.75 when mixed at home.

This dressing contains a little less "available" but a little more total phosphoric acid than that given in the 320 pounds of superphosphate applied during the rotation to Plot 2 (80 pounds each on corn and oats and 160 pounds on wheat), and carries in addition about twelve pounds of organic nitrogen, (in the tankage) as against the seventy-five pounds of nitrate nitrogen used on Plots 5, 6, 9 and 11. When this tankage is bought at retail its nitrogen costs about seven and one-half cents per pound, (equivalent to six and one-fourth cents for "ammonia") after allowing five cents per pound for its available phosphoric acid, and this is less than half the cost of nitrogen in nitrate of soda; while its cost in nitrate of soda is considerably less than in the average factory-mixed fertilizer.

It will be observed that the total value of the increase on Plot 30 falls only about two dollars below that on Plot 6, although the cost of the fertilizer for Plot 30 is but little more than one-fourth that for Plot 6, the quantity being half as great. In percentage composition the fertilizer used on Plot 30 carries about 3½ per cent. "ammonia," 9 per cent. available and 10 per cent. total phosphoric acid, and 2½ per cent. potash. Its cost, when the materials are bought at retail, is about $18 per ton, freight paid, as against about $25 for a factory-mixed fertilizer of equivalent composition.

Whether this fertilizer is being mixed in the best proportions, or used in the most economical quantity, the experiment does not clearly show; but it perhaps offers some useful suggestions. It will be observed that the corn increase on Plot 30 is approximately the same as the average of Plots 11 and 12, and is several times as large as that on Plot 2. There would seem, therefore, to be no encouragement to change either the composition or the quantity of this fertilizer, so far as the corn crop is concerned. The increase of oats on Plot 30 is only about half that on Plots 11 and 12, but on Plot 30 oats follows as a gleaner, receiving no fertilizer itself, whereas on Plots 11 and 12 it is directly fertilized. It is doubtful whether it would pay to add an additional dressing for the oats. When we come to the wheat, however, we find that the wheat lines on Plots 11 and 12 stretch far beyond those of either Plots 30 or 6, although the latter receives as much nitrogen as Plot 11. This point suggests the increase of both nitrogen and potash, especially the nitrogen, for the wheat. The increase of potash is further suggested by comparison of the wheat lines in Plots 6 and 14; the latter, as already stated, receives a smaller total quantity of fertilizer than the former, but that of Plot 14 contains potash, whereas that on Plot 6 contains none.

The undetermined problem is: How much nitrogen and potash may be added without going beyond the limit of profitable use? It would seem that the quantity of nitrogen might be increased nearly or quite to that used on Plot 11, provided the cost were reduced to that of tankage nitrogen, while the potash quantity must be left as indefinite.

Experiments on these points have been commenced at the substation (see Plots 32 to 36) but they have not had time as yet to furnish trustworthy answers to the questions proposed.

It may be, moreover, that when the clover has had time and opportunity to perform its function in the rotation the results will be considerably modified. It must be remembered that we are as yet discussing the effect of fertilizers on the first course of the rotation, and on crops grown practically free from the influence of clover.

For crops grown under similar conditions, this work at present would seem to justify the employment for corn or oats of a fertilizer of about the composition of that used on our Plot 30, but with the nitrogen and potash considerably increased for wheat.

Lines 18 and 20 in the diagram show the results of applications of barnyard manure to corn and wheat, 8 tons per acre to each crop, or 16 tons in the five years on Plot 18, and 4 tons per acre to each crop, or 8 tons in the five years on Plot 20. The most conspicuous effect of the manure, as contrasted with that of the chemical fertilizers, is the marked increase of the hay crops, a point which illustrates the slower action of the manure. The smaller dressing of manure contains approximately the same quantities of nitrogen, phosphoric acid and potash as are found in the total dressing of fertilizers on Plot 11, but the increase on Plot 20 is only about 60 per cent. that on Plot 11 in value Whether a greater residual effect from the manure may be carried over to the crops of subsequent rotations remains to be seen.

Valuing manure at 50 cents per ton—an ample allowance for drawing it from the barnyard and spreading on the field under ordinary conditions—it has yielded a larger net profit than any of the fertilizing mixtures used; or, putting it another way, a ton of manure has produced an average increase in the first rotation to the value of about $1.20 on Plot 18, and about $1.60 on Plot 20. While, however, the profit per ton has been larger from the very small application, the profit per acre has been a little larger from the larger application of manure, amounting to a fraction over nine dollars in each case in the average results. Taking the crops of 1897 alone, however, the manure has produced a total increase to the value of $2.25 per ton on Plot 20 and $1.75 per ton on Plot 18, yielding a net profit on Plot 20 of $14, and on Plot 18 of $20 over an estimate cost of 50 cents per ton for the manure, a larger net profit than that given by any combination of fertilizers used in this test, although several of these combinations have produced a considerably larger gross increase than the manure.

Attention is called to the relatively small increase in the oat crop from the manure. The manure is applied as a top dressing to both corn and wheat; consequently it is plowed under for the oat crop. The result is a striking commentary on the two methods of applying manure. The fertilizers in all cases are applied over the surface, being put in with the fertilizer drill just before seeding or planting.

2. Fertilizers in three-year rotation of potatoes, wheat and clover.

This test was continued during 1897 at the central station and both the sub-stations. At the central station a large crop of potatoes was harvested, notwithstanding the severe drouth, a result largely due to the careful cultivation given. On the heavier clay of the Northeastern sub-station the effects of the drouth were more severe, and the results of the test were so obscured that no comparisons can be made from them. At the Northwestern sub-station the crop was almost totally destroyed by blight.

The wheat crop was very good at the central and Northeastern stations, reaching forty bushels and upwards per acre on the most heavily fertilized plots at both places. At the Northwestern sub-station only a medium crop was harvested.

A fine crop of clover was harvested at the central station. That a the Northeastern sub-station was very light, owing to poor stand and small growth combined, while that at the Northwestern sub-station was so irregular in stand that no attempt was made to harvest the plots separately. The attempt to grow clover on the yellow sand of this sub-station has thus far resulted chiefly in failure. Even when the clover starts to grow it is often either smothered or carried away in the drifting sand.

Table IX shows the distribution of fertilizers in this test. Table X gives the total quantity and cost of fertilizers used and Tables XI to XIV give the results of the test to date.

TABLE IX—PLAN OF FERTILIZING IN THREE-YEAR ROTATION.

Fertilizers in pounds per acre.

Plot No.	On potatoes.			On wheat.		
	Super-phos-phate.[1]	Nitrate soda.	Muriate potash.	Super-phos-phate.[1]	Nitrate soda.[2]	Muriate potash.
1						
2	160			160		
3			100			100
4						
5		80			160	
6	160	80		160	160	
7						
8	160		100	160		100
9		80	100		160	100
10						
11	160	80	100	160	160	100
12	160	160	100	160	240	100
13						
14	320	160	200	160	160	100
15	480	320	300			
16						
17				A		
18				B		
19						
20	80	C	85	D		70
21	120	E	95	110	F	90
22						
23	150	G	100	150	H	100
24	160	I	100	160	K	100
25						
26	L	55	100	L	135	100
27	M	80	100	M	160	100
28						
29	N	80	100	N	160	100
30	B					
31						
32				O		
33	P			P		
34						

Explanation.

A. Barnyard manure, 4 tons
B. " " 8 "
C. Wheat bran, 500 lbs.
D. " 1,000 "
E. Linseed oil meal, 250 lbs.
F. " 500 "
G. Dried blood, 100 lbs.
H. " 200 "
I Sulphate ammonia, 60 lbs.
K. " 120 "
L. Bone meal, 110 lbs.
M. Acid phosphate, 170 lbs., 1894–96, dissolved bone black, 140 lbs., 1887 and since.
N. Basic slag, 130 lbs.
O. Barnyard manure, 16 tons, beginning fall of 1886.
P. Acid phosphate, 100 lbs., tankage, 100 lbs., muriate of potash, 10 lbs., beginning, 1896.

[1]Superphosphate as dissolved bone black previous to 1897; as acid phosphate beginning with the spring of 1897.

[2]On wheat, one-third dried blood, applied in the fall, and two-thirds nitrate soda, applied in April; all other fertilizers for wheat are applied in the fall.

TABLE X—FERTILIZERS ON CROPS GROWN IN THREE-YEAR ROTATION.

Total quantity of fertilizing materials applied per acre during the three years of a rotation, with fertilizing constituents carried and cost of total application.

Plot No.	Fertilizing materials.				Fertilizing constituents.			Cost of fertilizers.
	Superphosphate.	Nitrate of soda.	Muriate of potash.	Total.	Phosphoric acid.	Nitrogen	Potash.	
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	
2	320	....	....	320	50	....	....	$2 40
3	....	....	200	200	....	....	100	5 00
5	....	240	....	240	....	38	....	6 00
6	320	240	....	560	50	38	....	8 40
8	320	....	200	500	50	....	100	7 40
9	....	240	200	440	....	38	100	11 00
11	320	240	200	760	50	38	100	13 40
12	320	400	200	920	50	64	100	17 40
14	480	320	300	1,100	75	50	150	19 10
15	480	320	300	1,100	75	50	150	19 10
17	A	....	....	....	25	38	40	2 00
18	B	....	....	....	50	75	80	4 00
20	80	C	155	1,735	50	38	100	11 98
21	230	D	185	1,165	50	40	100	13 85
23	320	E	200	820	50	38	100	11 15
24	320	F	200	700	50	36	100	12 80
26	G	190	200	610	50	38	100	11 95
27	H	240	200	760	50	38	100	13 40
29	I	240	200	700	50	38	100	13 40
30	K	....	....	....	50	75	80	4 00
32	L	....	....	....	100	150	160	8 00
33	M	....	....	420	50	12	10	3 75

A. Barnyard manure on wheat, 4 tons.
B. Barnyard manure on wheat, 8 tons.
C. Wheat bran, 1,500 pounds.
D. Linseed oil meal, 750 pounds.
E. Dried blood, 300 pounds.
F. Sulphate of ammonia, 180 pounds.
G. Raw bone meal, 220 pounds.
H. Acid phosphate, 340 pounds, 1894-96; dissolved bone black, 280 pounds, 1897 and since.
I. Basic slag, 260 pounds.
K. Barnyard manure on potatoes, 8 tons.
L. Barnyard manure on wheat, 16 tons.
M. Acid phosphate, 100 pounds; tankage, 100 pounds; muriate of potash, 10 pounds on potatoes and wheat.

TABLE XI—FERTILIZERS ON CROPS GROWN IN THREE-YEAR ROTATION AT CENTRAL STATION.

Yield per acre—1897.

Plot No.	Potatoes.			Wheat.		Hay.
	Large.	Small.	Total.	Grain.	Straw.	
1	181.1	28.5	209.6	33.67	3,530	5,350
2	183.2	27.4	210.6	35.25	3,685	4,750
3	179.8	24.1	203.9	38.00	3,380	4,750
4	158.0	24.7	182.7	35.50	3,570	4,500
5	168.8	23.9	192.7	38.50	4,210	4,700
6	199.1	27.9	227.0	39.25	4,245	4,420
7	165.2	25.3	190.5	34.17	3,340	4,180
8	192.0	26.2	218.2	39.83	3,780	4,250
9	192.7	23.5	216.2	45.67	4,160	4,450
10	166.2	25.5	191.7	36.17	3,710	4,320
11	190.5	28.7	219.2	45.00	4,400	4,430
12	194.3	27.0	221.3	48.00	4,820	4,790
13	148.5	26.3	174.8	37.33	3,810	4,430
14	195.2	21.6	216.8	47.75	4,635	4,620
15	206.7	26.6	233.3	44.00	4,210	4,350
16	141.8	24.8	166.6	37.50	3,700	4,600
17	152.0	25.3	177.3	37.83	3,730	4,550
18	156.3	22.3	178.6	34.33	3,290	5,120
19	140.3	26.8	167.1	32.92	3,215	3,900
20	188.3	28.0	216.3	33.58	3,045	4,430
21	191.7	26.1	217.8	36.83	3,390	3,750
22	150.5	27.5	178.0	31.17	2,980	3,920
23	191.3	26.7	218.0	35.50	3,330	3,800
24	179.2	23.8	203.0	38.67	3,730	4,440
25	147.8	27.5	175.3	32.50	3,100	4,820
26	169.7	29.0	198.7	43.92	4,465	4,390
27	181.8	24.7	206.5	43.42	4,415	4,210
28	164.7	19.8	184.5	34.50	3,130	4,470
29	190.2	23.6	213.8	41.17	4,030	4,460
30	215.7	22.8	238.5	34.67	3,170	3,880
31	164.2	22.3	186.5	33.67	3,130	4,240
32	151.7	22.5	174.2	39.17	3,470	4,730
33	138.3	25.7	164.0	39.17	3,550	4,620
34	122.8	25.5	148.3	30.83	2,850	4,320
*	154.2	25.4	179.6	34.16	3,339	4,421

* Average of unfertilized plots.

TABLE XII—FERTILIZERS ON CROPS GROWN IN THREE-YEAR ROTATION AT CENTRAL STATION.

Plot No.	Increase or decrease (—) per acre, 1897. Potatoes. Large.	Potatoes. Small.	Potatoes. Total.	Wheat. Grain.	Wheat. Straw.	Hay.	Total value of increase	Total cost of fertilizers.	Net gain from fertilizers.
	Bushels.	Bushels.	Bushels.	Bushels.	Pounds.	Lbs.			
2	9.8	0.2	10.0	0.97	142	—317	$4 04	$2 40	$1 64
3	14.1	—1.9	12.2	3.11	—177	—33	7 10	5 00	2 10
5	8.4	—1.0	7.4	3.44	717	307	7 20	6 00	1 79
6	36.3	2.8	39.1	4.64	828	133	20 99	8 40	12 59
8	26.5	0.8	27.3	4.99	317	23	15 45	7 40	8 05
9	26.8	—1.9	24.9	10.17	573	177	19 49	11 00	8 49
11	30.2	2.9	33.1	8.44	657	73	21 20	13 40	7 80
12	39.9	1.0	40.9	11.05	387	397	26 97	17 40	9 57
14	48.9	—4.2	44.7	10.36	862	133	31 45	19 10	12 35
15	62.7	1.3	64.0	6.56	473	—193	30 98	19 10	11 88
17	10.7	—0.2	10.5	1.86	192	183	6 52	2 00	3 52
18	15.5	—3.8	11.7	—0.12	—87	987	7 41	4 00	7 41
20	44.6	1.0	45.6	1.24	92	523	20 94	11 98	8 96
21	44.6	—1.2	43.4	5.08	332	—164	21 43	13 85	7 58
23	41.7	—0.8	40.9	3.89	310	—420	18 68	11 03	7 65
24	30.5	—3.7	26.8	6.61	670	—80	16 77	11 80	4 97
26	16.3	4.1	20.4	10.75	1,355	—313	18 75	11 95	6 85
27	22.7	2.3	25.0	9.59	1,295	—377	18 48	13 40	5 08
29	25.7	3.0	28.7	6.95	900	67	18 59	13 40	5 19
30	51.3	1.4	52.7	0.72	40	....	21 72	4 00	17 72
*32	....	....	....	6.45	433	....	5 81	....	....
*33	1.7	1.3	3.0	7.39	607	....	8 02	....	....

*The experiment was not begun on plots 32 and 33 until 1896.

TABLE XIII—FERTILIZERS ON CROPS GROWN IN THREE-YEAR ROTATION AT CENTRAL STATION.

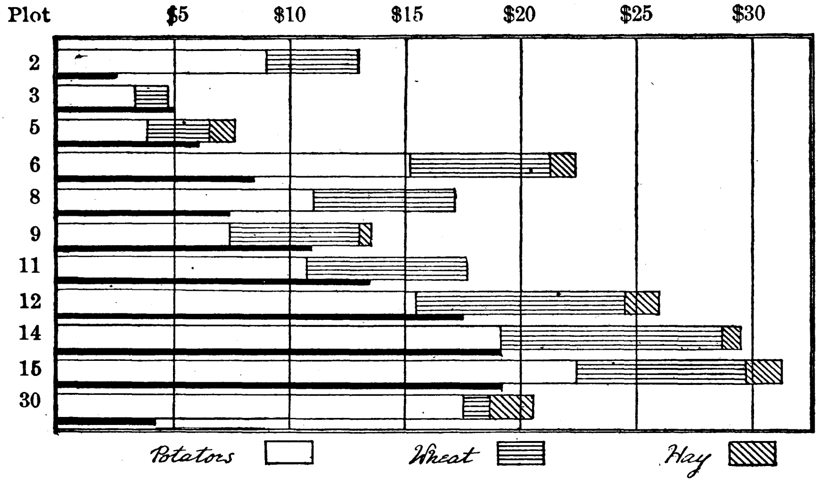
Average Results for three Years, 1894-97.

Plot No.	Average yield per acre.				Average increase or decrease (—) per acre.				Total value of increase	Total cost of fertilizer.	Net gain or loss (—) from fertilizer.
	Potatoes.	Wheat.		Hay.	Potatoes.	Wheat.		Hay.			
		Grain.	Straw.			Grain.	Straw.				
	Bu.	Bu.	Lbs.	Lbs.	Bu.	Bu.	Lbs.	Lbs.			
1......	154.8	19.67	1,883	5,300	....	....	....	....	....	....	....
2......	179.9	23.00	2,220	4,875	22.6	4.34	411	—142	$12 70	$2 40	$10 30
3......	167.7	19.56	1,703	4,450	8.0	1.91	—33	—283	3 83	5 00	—1 17
4......	162.2	16.64	1,662	4,450	....	....	....	....	....	....	....
5......	170.1	19.15	2,024	4,850	9.7	2.68	395	353	7 68	6 00	1 68
6......	196.6	22.80	2,165	4,925	38.1	6.49	570	382	22 44	8 40	14 04
7......	156.7	16.14	1,562	4,590	....	....	....	....	....	....	....
8......	184.3	23.43	2,031	4,550	27.4	6.96	414	—22	17 09	7 40	9 69
9......	175.5	23.14	2,032	4,740	18.4	6.35	361	187	13 54	11 00	2 54
10......	157.3	17.12	1,726	4,535	....	....	....	....	....	....	....
11......	182.5	25.48	2,271	4,440	27.1	8.20	543	—22	18 15	13 40	4 75
12......	192.3	27.10	2,567	4,895	38.8	9.67	838	507	26 03	17 40	8 63
13......	151.6	17.59	1,731	4,315	....	....	....	....	....	....	....
14......	198.9	28.14	2,445	4,485	47.9	10.58	740	270	29 54	19 10	10 44
15......	206.5	25.83	2,177	4,615	56.0	8.31	497	500	31 29	19 10	12 19
16......	149.9	17.49	1,654	4,015	....	....	....	....	....	....	....
17......	144.6	19.00	1,770	4.605	**10.5	2.32	198	703	8 46	2 00	6 46
18	142.9	18.64	1,672	5,035	**11.7	2.78	163	1,247	10 89	4 00	6 89
19......	140.9	15.05	1,437	3,675	....	....	....	....	....	....	....
20......	186.4	17.23	1,489	4,515	42.6	2.37	72	837	21 46	11 98	9 48
21......	182.4	21.37	1,831	3,975	35.7	6.69	434	294	21 16	13 85	7 31
22......	149.6	14.49	1,377	3,685	....	....	....	....	....	....	....
23......	189.2	20.33	1,750	3,590	42.2	5.55	350	—137	20 96	11 15	9 81
24......	177.0	21.44	1,783	3,945	32.5	6.37	361	177	19 17	12 80	6 37
25......	141.9	15.36	1,445	3,810	....	....	....	....	....	....	....
26......	160.1	22.82	2,197	3,720	16.4	6.27	711	—98	12 35	11 95	0 40
27......	172.7	23.44	2,127	3,845	27.2	7.71	600	18	18 00	13 40	4 60
28......	147.3	15.92	1,568	3,835	....	....	....	....	....	....	....
29......	165.7	23.65	2,164	4,555	19.8	7.97	644	822	17 73	13 40	4 73
30......	188.1	16.75	1,518	4,244	43.6	1.31	45	612	20 39	4 00	16 39
31......	143.1	15.20	1,425	3,530	....	....	....	....	....	....	....
*	150.5	16.43	1,588	4,158							

*Average of unfertilized plots. **One crop.

The experiment was not begun on plots 32 and 33 until 1896.

DIAGRAM II—AVERAGE VALUE OF INCREASE AND COST OF FERTILIZERS PER ACRE IN THREE-YEAR ROTATION.



In Diagram II are shown the average results of this test at the central station to date. It includes the average of four crops of potatoes, three of wheat and two of hay. In computing values, potatoes are estimated at 40 cents per bushel, wheat at 80 cents and hay at $6 per ton,

In this test, as in the cereal rotation, phosphoric acid has been the dominant factor in producing increase in yield, but it has paid to reinforce the phosphoric acid with nitrogen, as shown on Plot 6. This plot shows the largest net profit of any in the series, except No. 30, receiving barnyard manure; for while the addition of potash has increased the yield, as shown on Plot 11, yet the increase has not been proportionate to the increased cost of the fertilizer.

It will be seen that at the valuations given the increase of crop has more than paid the cost of the fertilizer in every case, except where potash was used alone, and in many cases there has been a handsome profit. In several cases the increase in the potato crop alone has paid the cost of fertilizers for both potatoes and wheat, leaving the increase in wheat and hay as clear profit.

It will be observed that the value of the increase from the potato crop runs about twice as much as that from the wheat and hay crops combined, at the rate at which these crops are valued in the diagram. If the three crops were reduced to their actual dry substance, however, and the increase were computed on that basis, we would find that the increase of dry substance in potatoes and wheat has been approximately equal. A bushel of potatoes contains about 12½ pounds of dry substance, a bushel of wheat about 54 pounds; therefore, the pound of dry substance in wheat at 80 cents per bushel brings 1½ cent, a price which would be equivalent to about 19 cents per bushel for potatoes. It is therefore the larger relative price which the potatoes bring which has most to do in the larger returns they show for fertilizers.

Attention is called to the very small effect thus far shown by the manure on the wheat and hay crops. The manure on this plot is applied as a top dressing to the potato crop only and the ground has been plowed again for the wheat crops which are included in the results given. The results thus confirm those of the cereal rotation in showing the inadvisability of plowing under manure.

THE THREE-YEAR ROTATION AT THE SUB-STATIONS.

As already stated, the crops at the sub-stations have suffered to a greater extent than at the central station from unfavorable seasons. At the Northeastern station the first wheat crop, that of 1896, was totally destroyed by winter killing, and the clover and timothy sown with the wheat were severely injured. Two out of the three potato crops grown have been so injured by excessive rains, followed by drouth, that it is impossible to make any comparison between the yields, while both potato and clover crops for 1897 have been destroyed at the Northwestern station, as previously stated. In Table XIV is given the record of such crops as were harvested in 1897 in such condition as to justify comparisons. In the case of the hay crop the yields are quite irregular, and the most that can be safely said is that the fertilizers have in the general average produced a decided increase of crop.

TABLE XIV—FERTILIZERS ON CROPS GROWN IN THREE-YEAR ROTATION AT SUBSTATIONS.

Yield and increase or decrease (—) per acre, 1897.

Plot No.	Northeastern substation.						Northwestern substation.			
	Wheat.				Hay.		Wheat.			
	Yield per acre.		Inc. or dec. (—) per acre.		Yield per acre.	Inc. or dec. (—) per acre.	Yield per acre.		Inc. or dec. (—) per acre.	
	Grain.	Straw.	Grain.	Straw.			Grain.	Straw.	Grain.	Straw.
	Bush.	Pounds.	Bush.	Pounds.	Bush.	Pounds	Bush.	Pounds.	Bush.	Pounds.
1	26.42	2,255	....	....	1,560	....	13.00	1,180	....	....
2	31.50	3,310	8.63	1,423	1,760	720	19.00	2,060	4.94	837
3	32.33	2,660	9.46	773	1,120	80	14.67	1,520	—0.44	253
4	19.33	1,520	....	....	1,060	....	16.17	1,310	....	....
5	19.83	2,010	—0.12	390	2,000	960	14.67	1,740	0.83	583
6	34.50	3,130	14.55	1,508	1,160	120	14.67	1,800	3.17	797
7	20.58	1,725	....	....	1,280	....	9.17	850	....	....
8	34.58	3,205	15.71	1,558	1,640	600	15.33	1,460	6.27	613
9	22.33	1,860	3.46	113	960	—80	9.33	840	0.39	—23
10	17.17	1,570	....	....	820	....	8.83	870	....	....
11	39.33	3,640	21.58	1,005	2,260	1,220	12.67	1,240	2.84	310
12	41.67	4,067	23.92	2,425	1,620	580	16.83	1,470	6.00	480
13	18.33	1,700	....	....	1,080	....	11.83	1,050	....	....
14	42.67	4,280	25.38	2,658	1,960	920	11.67	1,110	—0.55	—143
15	31.83	2,770	14.54	1,148	2,580	1,540	13.83	1,050	1.22	—407
16	16.25	1,545	....	....	1,140	....	13.00	1,660	....	....
17	20.33	1,700	1.79	—107	1,120	80	14.83	1,610	0.72	—43
18	28.68	2,598	10.14	791	1,520	480	16.33	1,820	1.11	173
19	20.83	2,070	....	....	900	....	16.33	1,640	....	....
20	26.33	2,340	5.92	380	1,380	340	20.17	1,950	4.95	437
21	39.50	3,430	19.09	1,470	1,580	540	21.00	2,040	6.89	653
22	20.00	1,850	....	....	1,260	....	13.00	1,260	....	....
23	34.00	3,000	15.13	1,148	1,980	940	....	....	....	....
24	35.84	3,850	15.97	1,998	1,800	760	....	....	....	....
25	19.75	1,855	....	....	960	....	....	....	....	....
26	39.79	3,912	19.38	1,954	1,760	720	....	....	....	....
27	36 83	3,396	16.42	1,438	1,420	380	....	....	....	....
28	21.01	2,061	....	....	....	....	....	....	....	....
29	40.75	3,855	19.88	1,935	2,040	1,000	....	....	....	....
30	19.33	2 675	—1.47	875	1,300	260	....	....	....	....
31	20.67	1,680	....	....	960	....	....	....	....	....
32	31.80	2,887	11.08	1,099	1,680	640	....	....	....	....
33	34.17	2,990	13.45	1,193	1,660	620	....	....	....	....
34	20.77	1,915	....	....	1,020	....	....	....	....	....
35	39.83	3,810	21.20	2,148	1,760	720	....	....	....	....
36	34.95	3,860	16 32	2,198	1,200	160	....	....	....	....
37	16.50	1,410	....	....	....	....	....	....	....	....
*	19.64	1,779	....	....	1,040	....	1,267	1,250	....	....

*Average of nnfertilized plots. The increase of hay in this table is calculated on this average

DIFFERENT CARRIERS OF NITROGEN AND PHOSPHORIC ACID.

Plot 11 in these experiments has received, in the course of the five years of the cereal rotation, 440 pounds of nitrate of soda and 40 pounds of dried blood per acre, an application estimated to carry 75 pounds of nitrogen at the average composition of these materials. It has also received 320 pounds of dissolved bone black per acre, calculated to carry 50 pounds of available phosphoric acid, and 260 pounds of muriate of potash per acre, containing 130 pounds of actual potash.

Plot 21 has received 1,500 pounds old process linseed oil meal per acre, which, on the basis of average analyses, would carry about 81 pounds of nitrogen, together with 25 pounds of phosphoric acid and 20 pounds of potash. This plot has received, in addition to the linseed meal, 170 pounds of dissolved bone black and 230 pounds of muriate of potash per acre, bringing up the total application to 51 pounds of phosphoric acid and 135 pounds of potash, no allowance being made for lack of availability in the phosphoric acid or potash of the linseed meal.

Plot 23 has received 600 pounds of dried blood per acre, as the sole carrier of nitrogen. Our analyses have indicated an average of 12½ per cent. of nitrogen for the blood used in these tests; on this basis the 600 pounds has carried the same quantity of nitrogen applied to Plot 11. As dried blood contains 1 to 2 per cent. of phosphoric acid, a corresponding reduction has been made in the dissolved bone black used on this plot.

On Plot 24 sulphate of ammonia has been used as the carrier of nitrogen. On the basis of 20½ per cent. nitrogen our application has carried about 74 pounds of nitrogen per acre.

Raw bone meal has been used on Plot 26, at the rate of 220 pounds per acre. It is usually estimated that the phosphoric acid of raw bone and animal matter all becomes ultimately available, but that it acts more slowly than the available phosphoric acid of dissolved bone black or acid phosphate, because of the fact that it is practically impossible to reduce the entire mass of a bone meal to the same degree of fineness that is attained with the other materials named. Assuming 23 per cent. of effective phosphoric acid in the bone meal, the phosphate carriers on Plots 11 and 26 would be equal. The raw bone used in these tests has shown 3½ to 4 per cent. of nitrogen, and 435 pounds of nitrate of soda has been added, making a total of 76 to 77 pounds of nitrogen per acre.

Plot 27 has received acid phosphate at the rate of 340 pounds per acre, on the basis of 14.7 per cent. available phosphoric acid, or 1 per cent. below the average composition of dissolved bone black.

On Plot 29 basic slag has been the carrier of phosphoric acid, the American product being used at the rate of 260 pounds per acre, on the basis of 19 per cent. phosphoric acid—a larger percentage than we have been able to find in some of the lots used.

TABLE XV—AVERAGE INCREASE PER ACRE FROM DIFFERENT CARRIERS OF NITROGEN AND PHOSPHORIC ACID.

Plot No.	Fertilizers.	Corn.		Oats.		Wheat.		Hay.		
		Average of four crops.						First year. Average of three crops.	Sec'nd year. Average of two crops.	Total.
		Grain	Stover	Grain	Straw	Grain	Straw			
	Carriers of nitrogen	Bush.	Lbs.	Bush.	Lbs.	Bush.	Lbs.	Lbs.	Lbs.	Lbs.
11	Nitrate of soda.....	8.74	282	13.57	575	8.98	1,268	1,233	378	1,611
21	Linseed oilmeal ...	6.62	335	7.46	378	9.14	1,295	1,083	468	1,551
23	Dried blood	6.76	283	9.91	324	6.69	860	1,158	428	1,586
24	Sulphate of ammonia...............	8.59	367	12.80	474	7.39	946	909	266	1,175
	Carriers of phosphoric acid.									
11*	Dissolved bone bl'ck	8.02	293	14.19	662	8.98	1,268	1,233	378	1,611
17	Wheat bran	6.10	163	8.10	327	5.38	706	1,031	316	1,347
26	Raw bone meal.....	5.96	361	11.96	362	6.20	983	1,271	483	1,754
27	Acid phosphate*...	6.21	190	11.24	540	7.16	1,063	816	131	947
29	Basic slag............	7.79	330	10.42	479	7.77	1,126	1,077	175	1,252

*In the spring of 1897 acid phosphate was substituted for dissolved bone black as the standard carrier of phosphoric acid in all these tests, and the dissolved bone black and acid phosphate were transposed on Plots 11 and 27; hence, in computing the averages here given, the increase for the corn and oats crops of 1897 was transposed.

This comparison is being repeated in both the rotations above described at Wooster and Strongville, but neither rotation has as yet been completed at the sub-station. At the central station there have been harvested in the cereal rotation four crops each of corn, oats and wheat, and five crops of hay—three of the first year, chiefly clover, and two of the second year, chiefly timothy. The average increase from these crops is given in Table XV.

The first section of this table shows that nitrate of soda has produced a larger increase of grain and hay in every crop in this rotation, except wheat, than any other carrier of nitrogen. The largest increase in wheat is found on the plot to which nitrogen was carried in linseed oil meal, while sulphate of ammonia stands second in oats and corn and third in wheat. If, however, we calculate the increase per pound of nitrogen applied we find that the apparent superiority of linseed meal on wheat is accounted for by the increased quantity of nitrogen carried in the application, and that sulphate of ammonia stands practically equal to nitrate of soda as a carrier of nitrogen to corn and oats.

The second section of this table shows a general superiority for dissolved bone black as a carrier of phosphoric acid, with raw bone meal, basic slag and acid phosphate following in the order named.

In order to bring out more clearly the results of this test, Table XVI has been compiled, in which is given the estimated quantities of nitrogen recovered in the increase on Plots 11, 21, 23 and 24, and of phosphoric acid recovered in that on Plots 11, 26, 27 and 29, both for each crop and for the total rotation, the straw or stover being included with the grain.

TABLE XVI—RECOVERY OF NITROGEN AND PHOSPHORIC ACID FROM DIFFERENT CARRIERS.

Crop.	Nitrogen recovered from Plot No. —				Phosphoric acid recovered from Plot No.—				
	11	21	23	24	11	17	26	27	29
Corn	10.74	8.93	8.79	11.22	3.97	2.86	3.32	2.97	3 77
Oats	11.95	6.97	8.10	10.82	4.15	2.26	3.07	3.32	3.03
Wheat	18.77	19.12	13.55	14.95	5.00	2.95	3.55	4.04	4.35
Hay	24.16	23.28	23.79	17.64	5.80	4.83	6.32	3.41	4.51
Total	65.62	58.30	54.23	54.63	18.92	12.92	16.26	13.74	15.66

As about 75 pounds of nitrogen and 50 pounds of phosphoric acid are applied during the rotation it will be observed that the total recovery on Plot 11 has been about 87 per cent. of the nitrogen applied and about 40 per cent. of the phosphoric acid.

Taking the recovery of nitrogen and phosphoric acid on this plot as 100, and making allowance for differences in quantity of nitrogen actually applied, the comparative recovery from the other carriers may be stated as follows:

Carriers of Nitrogen.

Nitrate of soda	100
Sulphate of ammonia	84
Dried blood	83
Linseed oil meal	82

Carriers of Phosphoric Acid.

Dissolved bone black	100
Raw bone meal	86
Basic slag	83
Acid phosphate	78
Wheat bran	68

Previous to 1897 the acid phosphate used in these tests was bought on a represented analysis of 14 to 16 per cent. available phosphoric acid, and for that year of 15 to 17 per cent. Our field tests would seem to indicate that the available phosphoric acid of acid phosphate is not more effective than the total phosphoric acid in fine raw bone meal.

In the experiments in the use of fertilizers on crops grown continuously on the same land, which have been carried on by this Station since 1888 at Columbus, nitrate of soda and sulphate of ammonia have been compared as carriers of nitrogen, and dissolved bone black, acid phosphate and basic slag, as carriers of phosphoric acid. In the average results thus far attained nitrate of soda has shown practically the same superiority over sulphate of ammonia as a nitrogen carrier that is indicated in the tests herein reported, but the superiority of dissolved bone black as a carrier of phosphoric acid is not so plainly manifest, and we have hitherto interpreted the results as indicating an equal effectiveness for the unit of "available" phosphoric acid, whether carried in dissolved bone black, acid phosphate or basic slag.

We regard the rotation experiments now under way as likely to give a more trustworthy indication of the actual value of these materials than those in continuous culture, both because a very much larger number of plots is under test in these experiments, thus to some extent eliminating the risk of being led to a wrong conclusion by natural variations in the fertility of the plots, and because the rotating of the crops admits a more complete utilization of the fertilizing materials than does the constant culture of the same crop on the same land.

The experiments do not furnish a direct comparison between tankage and the other materials used as carriers of nitrogen and phosphoric acid, as both nitrogen and potash were used in smaller quantity on the tankage plot (No. 30) than on the standard plots. The general effectiveness of the fertilizer used on this plot, however, is such as to justify the assumption that the nitrogen of finely ground tankage may safely be rated with that of dried blood or linseed oil meal, and its phosphoric acid may certainly be compared with that of raw bone meal, since it is derived from the same source.

SUMMARY.

The results of these experiments apparently justify the conclusion that, for the soils and crops under test, phosphoric acid is at present the most important constitutent of a fertilizer, with nitrogen and potash following in the order named.

The largest increase is only obtained when the fertilizer contains all three of these constitutents; but it does not as yet seem necessary to use nitrogen and potash in so large proportion, relatively to phosphoric acid, as would be indicated by the chemical composition of the crops.

Apparently, phosphoric acid should considerably exceed either nitrogen or potash in quantity in a fertilizer for corn, oats or potatoes, while for wheat the proportion of nitrogen may closely approximate that of phosphoric acid.

Nitrate of soda is apparently the most effective carrier of nitrogen in common use as a fertilizer, but it can seldom be used with economy in Ohio because of the relatively high cost of its nitrogen.

Slaughterhouse tankage, which is the carrier of "ammonia" in practically all the factory-mixed fertilizers sold in this state, is probably a less effective carrier of nitrogen than nitrate of soda; but the cost of nitrogen in unmixed tankage, when due allowance is made for the phosphoric acid carried by the tankage, is so much less than in nitrate of soda, that tankage becomes a much more economical source of nitrogen to the Ohio farmer than nitrate of soda. This advantage in tankage disappears, however, when it is purchased in the ordinary factory-mixed fertilizer, since the price at which such fertilizers are generally sold brings the cost of their nitrogen to a higher figure than its necessary cost in nitrate of soda, while the experiments reported in Bulletin 93 of this station indicate that the nitrogen of the factory-mixed fertilizer is not more effective than that of ordinary tankage.

Dissolved bone black is apparently a more effective carrier of phosphoric acid than raw bone meal or acid phosphate; but dissolved bone black, like nitrate of soda, is seldom or never used in the compounding of factory-mixed fertilizers in Ohio, because of the lower cost of phosphoric acid in other materials.

Acid phosphate, on account of its comparative cheapness and large supply, has become the standard carrier of fertilizer phosphoric acid. Our experiments indicate that commercial acid phosphate, like slaughterhouse tankage, is variable in composition, and both materials should only be bought on a guaranteed analysis.

Our experiments fully support the inference that the phosphoric acid of bone meal and tankage, when these materials are finely ground, is quite as effective, pound for pound, as the "available" phosphoric acid of acid phosphate; and that these materials, unlike bone black and Carolina rock, require no treatment with sulphuric acid to make their phosphoric acid available, provided only the grinding be done with sufficient thoroughness. Investigations reported in Bulletin 93 indicate that there has been a decided improvement in grinding within recent years.

Basic slag appears to stand next to dissolved bone black in effectiveness as a carrier of phosphoric acid. Apparently this result is in part at least due to the superior mechanical condition of the slag meal, as it is an extremely fine powder. This material is not treated with acid.

These experiments show that the fertilizing constituents of barnyard manure act more slowly than those of commercial fertilizers; but as they cost much less in manure it becomes the cheapest fertilizer.

The advantage of applying manure to the surface, instead of plowing it under, is strikingly shown.

Of the crops grown in these experiments, potatoes have given the largest return for the fertilizer; but this has been due, not to any larger recovery by the potatoes of the fertilizing constituents applied, but to the relatively higher value of the potatoes. Of the cereal crops, wheat has shown a larger return, both in value of increase and in recovery of fertilizing constituents applied in the fertilizer, than either corn or oats; while the two successive hay crops following the wheat, although receiving no additional dressing of fertilizers, have yielded a still larger recovery of fertilizing constituents than the wheat.

The increase from fertilizers in these experiments was unusually large in 1897, this being the first season in the experiments of this station, in which the cereal crops have given a general increase sufficient to cover the cost of the fertilizer. In the average of the four seasons, 1894–97, however, the value of the increase of crop has only equalled the cost of the fertilizer in a few instances. The most profitable increase in the average is found in the plot which has received a fertilizer mixed from tankage and acid phosphate, with a small addition of muriate of potash, and used only on corn and wheat. Even in this case a considerable portion of the profit would have disappeared, had the fertilizer been purchased at the cost of factory-mixed fertilizers of equivalent composition.

CONCLUSION.

In the first report of this station upon the experiments with fertilizers now in progress the following conclusion was drawn:

"The most important conclusion to be drawn from these tests is * * * that in very many, if not the majority of cases, neither wheat nor corn will return sufficient increase of crop to cover the cost of any artificial fertilizer, at present prices of grain and fertilizers respectively.

"The experiments do not, however furnish conclusive proof that commercial fertilizers cannot be used with profit in Ohio. Most persons who use these fertilizers on wheat do so in the belief that the grass or clover following the wheat is much improved by the fertilizer, and English experiments indicate that there is some justification for this belief. Whether this improvement is sufficient to compensate the average loss which must result in the wheat is a question which should be subjected to the test of systematic experiment."

This was written in the winter of 1889-90, when the farm price of wheat was about 70 cents per bushel, and of corn, less than 30 cents. At this time "ammonia" was valued by the fertilizer control stations at 19 to 20 cents per pound, available phosphoric acid at 8 to 8½ cents, and potash at 6 to 6½ cents, and Ohio farmers were paying $30 to $35 per ton for factory-mixed fertilizers of average composition.

For several years subsequently the prices of grain, wheat especially, ruled still lower than those just quoted, but there was no corresponding reduction in the price of fertilizers. From year to year the experiments of

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this station were continued, and although a regular increase was shown from the fertilizers, yet it was also shown that the cost of these fertilizers was too great, as compared with the value of the crops produced, at the low prices then current, to justify the use of such fertilizers as a regular factor in crop production in Ohio.

The point insisted upon was that the price of fertilizers was too high, in proportion to the value of the crops produced; not that the fertilizers did not produce increase of crop. On the contrary, this station's experiments constantly showed a larger increase of crop from certain artificial fertilizers than from barnyard manure.

These exhibits by the station led many farmers to a more careful study of the actual effects of fertilizers on their crops, with the result of bringing them to the same conclusions; others were driven to reduction in the use of fertilizers by the continued depression in the price of wheat, and for four years, there was no increase in the total sales of fertilizers in Ohio, although there was a constant increase in the number of brands licensed, and presumably of manufacturers, dealers and agents.

The result was a reduction in prices; and in the official report on fertilizers for 1897 of the Secretary of the Ohio State Board of Agriculture we find ammonia valued at 12 1-2 cents per pound, available phosphoric acid at 5 cents and potash as muriate at 5 1-4cents, a reduction of 20 to 40 per cent. on the valuations prevailing seven years previously, and corresponding to a reduction of $8 to $10 per ton in the price of factory-mixed fertilizers.

That this reduction is not greater than can be afforded is shown in the continued increase in the number of dealers in fertilizers and of brands upon which license is paid, and especially in the facts detailed in Bulletin 93 of this station, where it is shown that the materials from which the mixed fertilizers are compounded—tankage, acid phosphate and muriate of potash—may be purchased at such rates as to reduce the cost of ammonia at wholesale to 5 or 6 cents per pound or less, and that of available phosphoric acid and potash to 4 to 4 1-4 cents, freight to Ohio included, prices representing a cost per ton of mixed fertilizers of $15 to $17, or about half the rates at which such fertilizers were sold to farmers in 1890.

Since these materials are already in condition for use, requiring simply to be stirred together, if any mixing is desired, the acid phosphate being a dry powder, already acidulated; the tankage, a dry meal requiring no further treatment, and the muriate of potash, a dry salt, there is no reason why farmers should not club together, buy the materials by the carload and mix them together at home, thus saving a large item of cost; and in fact "home mixing associations" are being organized over the state for the purpose of effecting this saving. One such association will use 800 tons this season, reducing by several thousand dollars the cost of its members' fertilizer bills.

It has already been shown, in Bulletin 93, that the bare cost of mixing is but a small fraction of the saving which may be effected by purchasing the prepared materials and compounding the fertilizer at home; for, under the present conditions of the retail fertilizer trade, the mixers of proprietary brands must so adjust their prices as to cover the expenses of their general and local agents, and to insure against losses from bad debts, and a margin of $5 to $8 per ton is probably not too much to cover these items and give a fair profit to the various intermediaries between the proprietor of the brand and the consumer of the fertilizer, especially when the number of local agents becomes almost as great as that of consumers.

This station can have no interest to subserve, in urging farmers to mix their own fertilizers, except to save to those farmers a portion of their earnings, which are all too scanty at present prices of produce, and to stimulate a more thorough study of the principles underlying the intelligent use of fertilizers. So long as the farmer buys his fertilizers on the patent medicine plan he can make no progress in the actual knowledge of the needs of his crops and soil; but when he begins to ask for himself whether and why he needs nitrogen, phosphoric acid or potash, one or all, then he starts on the road to positive knowledge.

This advice, however, is the most distasteful possible to a large body of men who are directly or indirectly interested in the retail fertilizer trade, and who therefore take every opportunity to discredit the station's work. Were we to attempt to show that fertilizers produce no increase of crop these men would be well satisfied, for their answer would be given by the wheat fields of thousands of farmers—an answer the more emphatic because the apparent increase of wheat from fertilizers is often greater than the real increase, owing to the tendency to produce greater increase of straw than grain—but to insist that prices ought to be lower and to show the farmer how he may secure lower prices by avoiding the retail trade altogether is striking a most sensitive point, because it is one which cannot be defended.

The ultimate result of following the course recommended, however, will be to greatly extend the use of commercial fertilizers; to substitute an intelligent for a blind, hap-hazard method, and to replace the present most irrational and unhealthy system of long credit purchase at fictitious prices by cash buying at actual value; and the legitimate fertilizer trade will thus be benefited and not injured by the course which this station is pursuing.

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